

What is claimed is:

Sub  
B8

1. A method for determining a longest prefix match for a variable length search key by a computer processing device, comprising the acts of:

reading an input key as a search string;

using the N most significant bits of the input key as an index into a table representing a plurality of root nodes of search trees wherein each non-empty entry contains a pointer to a next branch in the search tree or a leaf;

determining if the pointer in a non-empty table entry points to a leaf or a next branch of the corresponding search tree;

reading the next branch contents if the pointer does not point to the leaf of the corresponding search tree and comparing the prefix represented by the next branch with the input key to find a distinguishing bit position;

reading a leaf pattern when the leaf of a corresponding search tree is reached and comparing the leaf pattern with the input key to determine if the leaf pattern matches the input key; and returning the longest prefix match found for the input key to a requesting application.

- Sub  
CL 1
2. The method for determining the longest prefix match of claim 1 wherein the table representing a plurality of root nodes of search trees contains  $2^N$  entries.
  3. The method for determining the longest prefix match of claim 1 wherein the computer processing device is a network processor.
  4. The method for determining the longest prefix match of claim 1 wherein the contents of the next branch of the corresponding search tree points to another next branch.

5. The method for determining the longest prefix match of claim 1 wherein the contents of the next branch points to the leaf of the corresponding search tree.
6. The method for determining the longest prefix match of claim 1 wherein the contents of the next branch points to both a bird and to another next branch of the corresponding search tree.
7. The method for determining the longest prefix match of claim 6 wherein the bird represents a special type of leaf that represents a partial prefix match of the input key.
8. The method for determining the longest prefix match of claim 7 wherein the bird is placed on a bird stack along with an associated bit position.
9. The method for determining the longest prefix match of claim 8 further comprising testing the bird stack to determine if it is full.

10. The method for determining the longest prefix match of claim 9 further comprising, if the bird stack is not full, reading the contents of the next branch of the corresponding search tree.

11. The method for determining the longest prefix match of claim 9 further comprising, if the bird stack is full, flushing the bird stack.

12. The method for determining the longest prefix match of claim 11 wherein the act of flushing the bird stack comprises the acts of:

reading the contents of the birds from a memory location;

comparing the input key with the pattern stored in the contents of the bird memory location;

determining a distinguishing position which represents a first bit at which the bird pattern and the input key differ;

selecting the bird with the largest bit number that does not exceed the distinguishing position to keep in the bird stack; and

removing all other birds in the bird stack.

13. The method for determining the longest prefix match of claim 1 further comprising the act of terminating the search for the longest prefix match when the bit number of the next branch exceeds the length of the input key.

14. A computer readable medium containing a plurality of data structures for finding a longest prefix match for a variable length search key, comprising:

a pattern or key that is to be searched;

a direct table that stores a first address location for a search tree;

a plurality of pattern search control blocks that each represent a branch in the search tree;

at least one bird representing a partial match of the input key; and

a plurality of leaves wherein each leaf is an address location for the result of a search.

15. The computer readable medium containing a plurality of data structures for finding the longest prefix match of

~~her compr  
a tree sea~~

[illegible]

16. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 15 wherein the lookup definition table comprises entries that define a physical memory that the tree resides in, a size of the key and leaf, and a type of search to be performed.
17. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 14 wherein the lookup definition table is implemented in a plurality of memories.
18. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 14 wherein a format for a direct table entry includes at least one of a search control block; a next pattern address that point to a next pattern search control block; a leaf control block address that points to a leaf or result; a next bit or bits to test; and a direct leaf.

19. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 14 wherein a format for a pattern search control block includes at least one of a search control block; a next pattern address that point to a next pattern search control block; a leaf control block address that points to a leaf or result; and a next bit or bits to test.
20. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 14 wherein a leaf data structure includes at least one of a leaf chaining pointer; a prefix length; a pattern to be compared to the search key; and variable user data.
21. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 18 wherein the direct leaf is stored directly in a direct table entry and includes a search control block and a pattern to be compared to a search key.



22. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 14 wherein a pattern search control block is inserted in the search tree at a position where the leaf patterns differ.
23. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 14 wherein a pattern search control block has a shape defined by a width of one and a height of one and is stored in a memory that has a line length of at least 64 bits.
24. The computer readable medium containing a plurality of data structures for finding the longest prefix match of claim 14 wherein a pattern search control block has a shape defined by a width of one and a height of two and is stored in a memory of at least 36 bits.

25. An apparatus fabricated on a semiconductor substrate for determining a longest prefix match for a variable length search key, comprising:

an embedded processor complex including a plurality of protocol processors and an internal control point processor that provide frame processing;

a plurality of hardware accelerator co-processors accessible to each protocol processor and providing high speed pattern searching, data manipulation, and frame parsing;

a plurality of programmable memory devices that store a plurality of data structures that represent at least one search tree, wherein the data structures include a direct table, a pattern search control block, a bird and a leaf; and

an control memory arbiter that controls the access of each protocol processor to the plurality of memory devices.

26. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 25 further comprising a tree search engine that operates in parallel with protocol processor execution to perform tree search instructions including memory reads and writes and memory range checking.
27. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 25 wherein the plurality of memory devices further comprises at least one of internal static random access memory, external static random access memory, and external dynamic random access memory.
28. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 25 wherein the control memory arbiter manages control memory operations by allocating memory cycles between the plurality of protocol processors and the plurality of memory devices.

29. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 25 wherein each protocol processor comprises a primary data buffer, a scratch pad data buffer and control registers for data store operations.
30. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 25 further comprising a hash box component that performs a no hash function on the search key with a resulting hashed key being equal to the search key.
31. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 25 further comprising a programmable search key register and a programmable hashed key register.
32. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 31 further comprising a programmable color key register to enable sharing a single table data structure among a plurality of independent search trees.

33. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 32 wherein the contents of the color register, if enabled, are appended to the hash output to produce a final hashed key.

34. The apparatus fabricated on a semiconductor substrate for determining the longest prefix match of claim 32 wherein if the color register is not enabled, an equivalent number of zeros are appended to the hash output to produce a final hashed key.

35. A computer readable medium containing a program product for determining a longest prefix match for a variable length search key, comprising:

program instructions that read an input key as a search string;

program instructions that use the N most significant bits of the input key as an index into a table representing a plurality of root nodes of search trees wherein each non-empty



36. The computer program product for determining the longest prefix match of claim 35 wherein the table representing a plurality of root nodes of search trees contains  $2^N$  entries.
37. The computer program product for determining the longest prefix match of claim 35 wherein the contents of the next branch of the corresponding search tree points to another next branch.
38. The computer program product for determining the longest prefix match of claim 35 wherein the contents of the next branch points to the leaf of the corresponding search tree.
39. The computer program product for determining the longest prefix match of claim 35 wherein the contents of the next branch points to both a bird and to another next branch of the corresponding search tree.

40. The computer program product for determining the longest prefix match of claim 39 wherein the bird represents a special type of leaf that is in the middle of a search tree branch.
41. The computer program product for determining the longest prefix match of claim 40 wherein the bird is placed on a bird stack along with an associated bit position.
42. The computer program product for determining the longest prefix match of claim 41 further comprising program instructions that test the bird stack to determine if it is full.
43. The computer program product for determining the longest prefix match of claim 42 further comprising program instructions that read the contents of the next branch of the corresponding search tree if the bird stack is not full.
44. The computer program product for determining the longest prefix match of claim 42 further comprising program



instructions that flush the bird stack if the bird stack is full.

45. The computer program product for determining the longest prefix match of claim 44 wherein the act of program instructions that flush the bird stack comprises:

program instructions that read the contents of the birds from a memory location;

program instructions that compare the hashed key with the pattern stored in the contents of the bird memory location;

program instructions that determine a distinguishing position which represents a first bit at which the bird pattern and the hashed key differ;

program instructions that select the bird with the largest bit number that does not exceed the distinguishing position to keep in the bird stack; and

program instructions that remove all other birds in the bird stack.

46. The computer program product for determining the longest prefix match of claim 35 further comprising program instructions that terminate the search for the longest prefix match when the bit number of the next branch exceeds the length of the hashed key.

*add 10*